Marine Physical Laboratory

Mid-Frequency Source Array Engineering Salaries

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A mid-frequency (~850 Hz) source-receive array has been fabricated for use in demonstrating enhanced operation of offboard active surveillance systems using phase conjugation (time reversal "mirror") concepts. The source-receive array and its companion surface buoy operate in an autonomous fashion thus facilitating single ship operations for carrying out experimental work. Personnel support for system fabrication was provided by this grant. The equipment for the system was supported separately under grant N00014-01-1-0799.

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Mid-Frequency Source-Receive Array – Engineering Salaries
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Abstract

A mid-frequency (~850 Hz) source-receive array has been fabricated for use in demonstrating enhanced operation of offboard active surveillance systems using phase conjugation (time reversal "mirror") concepts. The source-receive array and its companion surface buoy operate in an autonomous fashion thus facilitating single ship operations for carrying out experimental work. Personnel support for system fabrication was provided by this grant. The equipment for the system was supported separately under grant N00014-01-1-0799.

Time Reversal Mirror Concept

A phase conjugate mirror time reverses the incident signal precisely returning it to its original source location. This phenomenon occurs independent of the complexity of the medium. The time reversal process can be accomplished by the implementation of a retransmission procedure (see Fig. 1). A signal received at an array is time reversed and retransmitted. A source array excited by the phase conjugated (time reversed) signal received at the array position will focus at the position of the radiating source. The medium fluctuations are embedded in the received signal so that if retransmission can occur on a time scale less than the dominant fluctuations, the medium variability will be eliminated since one back propagates and "undoes" the variability.

Source-Receive Array System Description

The mid-frequency source-receive array system is an enhancement of existing electronics and surface buoy hardware from a previously-funded (FY98) DURIP which focused on high frequencies (~3.5 kHz). The existing high frequency system has been upgraded so that it can operate at both 850 Hz and 3.5 kHz.

The high frequency phase conjugation array consists of a vertical array of 29 source/receive transducers operating nominally in the 3-4 kHz band, an underwater pressure case containing the source/receive electronics, and a surface buoy providing battery power, system control, and wireless local area network (LAN) connectivity (see Fig. 2)) [1]. The upgraded system has the same general configuration with an array of 850 Hz transducers replacing the array of 3.5 kHz transducers.

Mid-Frequency Source-Receive Array Fabrication

Fabrication of the mid-frequency source-receive array involved acquiring mid-frequency (~850 Hz) transducers to populate the 29-element array (plus spares), calibrating their transmit (TVR) and receive (FFVS) characteristics, and making appropriate modifications to the existing electronics packaging inside the pressure case to accommodate new transformers enabling operation of the power amplifiers at both 850 Hz and 3.5 kHz. The fundamental design of the source/receive electronics in the pressure case and the surface buoy hardware have remained unchanged and are described in detail in [1].

Note that an integrated array cable with molded take-outs was included in the original proposal. Permission was requested to substitute the purchase of a new steel armored umbilical cable connecting the pressure case and surface buoy. Testing of the existing umbilical cable showed it to be unreliable. In place of the integrated array cable, the original approach of using individual coaxial cables (bundled with spiral wrap) connecting the transducers to the pressure case was continued.

A significant amount of effort was spent calibrating the transducers and interacting with the transducer manufacturer (Marine Acoustics Limited). Although a standard transducer in their product line, the MAL Sonoflex 850 transducers proved problematic. The original set of transducers which were delivered failed their acceptance test with substantial deviations from the advertised specifications in both source level and resonance frequency. MAL was responsive and subsequently supplied a replacement set of transducers. The measured calibration characteristics of these transducers (both transmit (TVR) and receive (FFVS)) are provided in Figs. 3-6. Note the substantial variation in resonance characteristics across the set of transducers at a common depth (Figs. 3-4) and for a given transducer as a function of depth (Figs. 5-6). At the nominal TVR specification of 131 dB re 1 μPa/V, each transducer of the mid-frequency source-receive array has a maximum output source level of 189 dB re 1 μPa.

The mid-frequency transducers were assembled into a source-receive array and taken to sea during the FAF-03 (Focused Acoustic Fields 2003) experiment sponsored separately by the Office of Naval Research and carried out jointly with the NATO SACLANT Undersea Research Centre. Fig. 7 shows the transducers configured for in-situ depth testing early in FAF-03. Subsequently, the source-receive array was deployed as a 78 m aperture vertical array. Shown in Fig. 8 are the transducers arranged for deployment on the back deck of the R/V Alliance.

The mid-frequency source-receive array did operate effectively during FAF-03. Results from carrying out time reversal focusing over a 10 km range for a period of 55 min are shown in Fig. 9.

References

[1] W.S. Hodgkiss, J.D. Skinner, G.E. Edmonds, R.A. Harriss, and D.E. Ensberg, "A high frequency phase conjugation array," Proc. OCEANS 2001: 1581-1585 (2001).

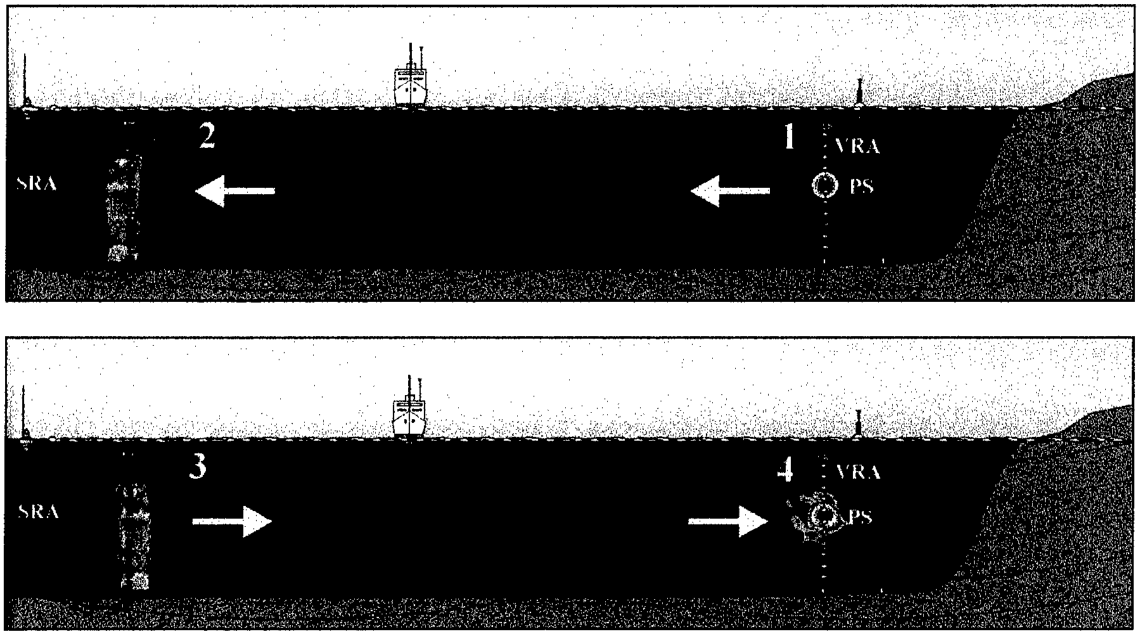

Fig. 1. Time reversal process implemented by a retransmission procedure.

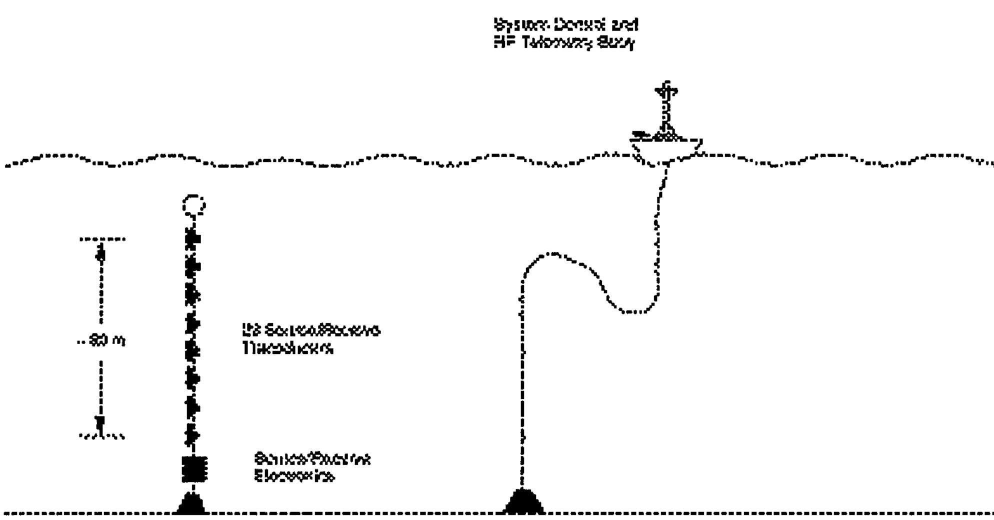

Fig. 2. Phase conjugation array system consisting of 29 source/receive transducers spanning an aperture of 78 m, an underwater pressure case containing the source/receive electronics, and a surface buoy providing battery power, system control, and wireless local area network (LAN) connectivity.

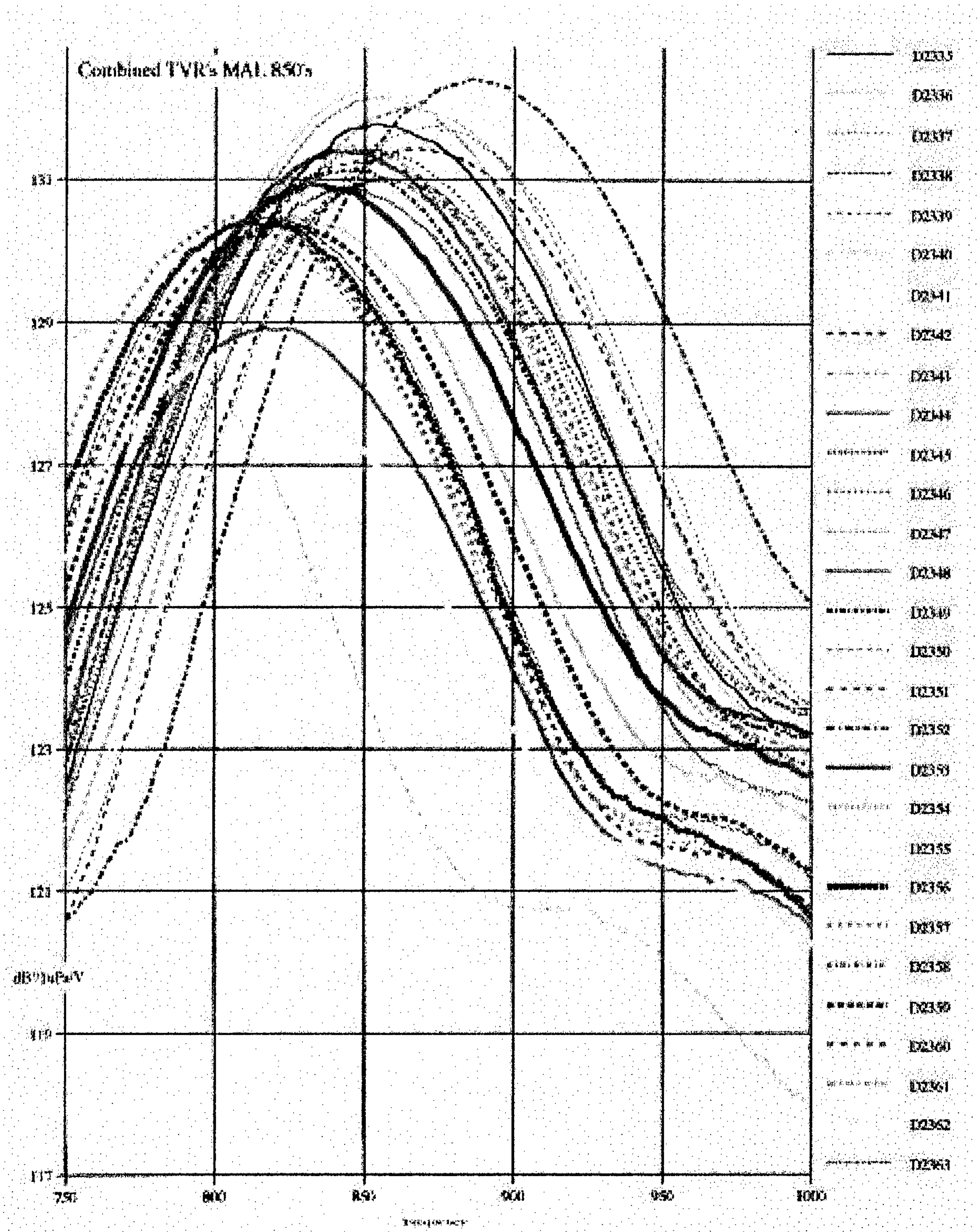

Fig. 3. Measured TVR characteristics of the mid-frequency transducer set at 12 m depth.

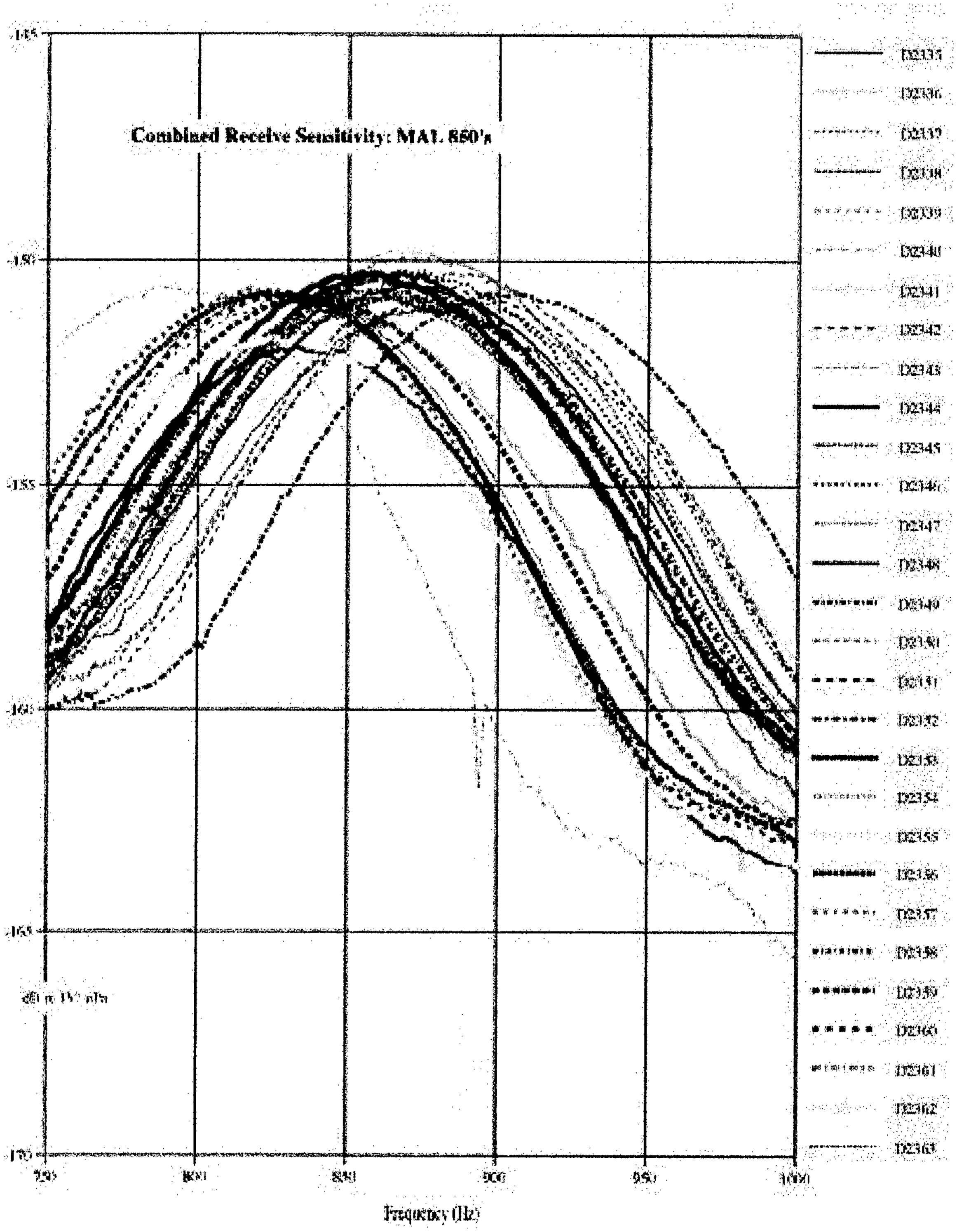

Fig. 4. Measured FFVS characteristics of the mid-frequency transducer set at 12 m depth.

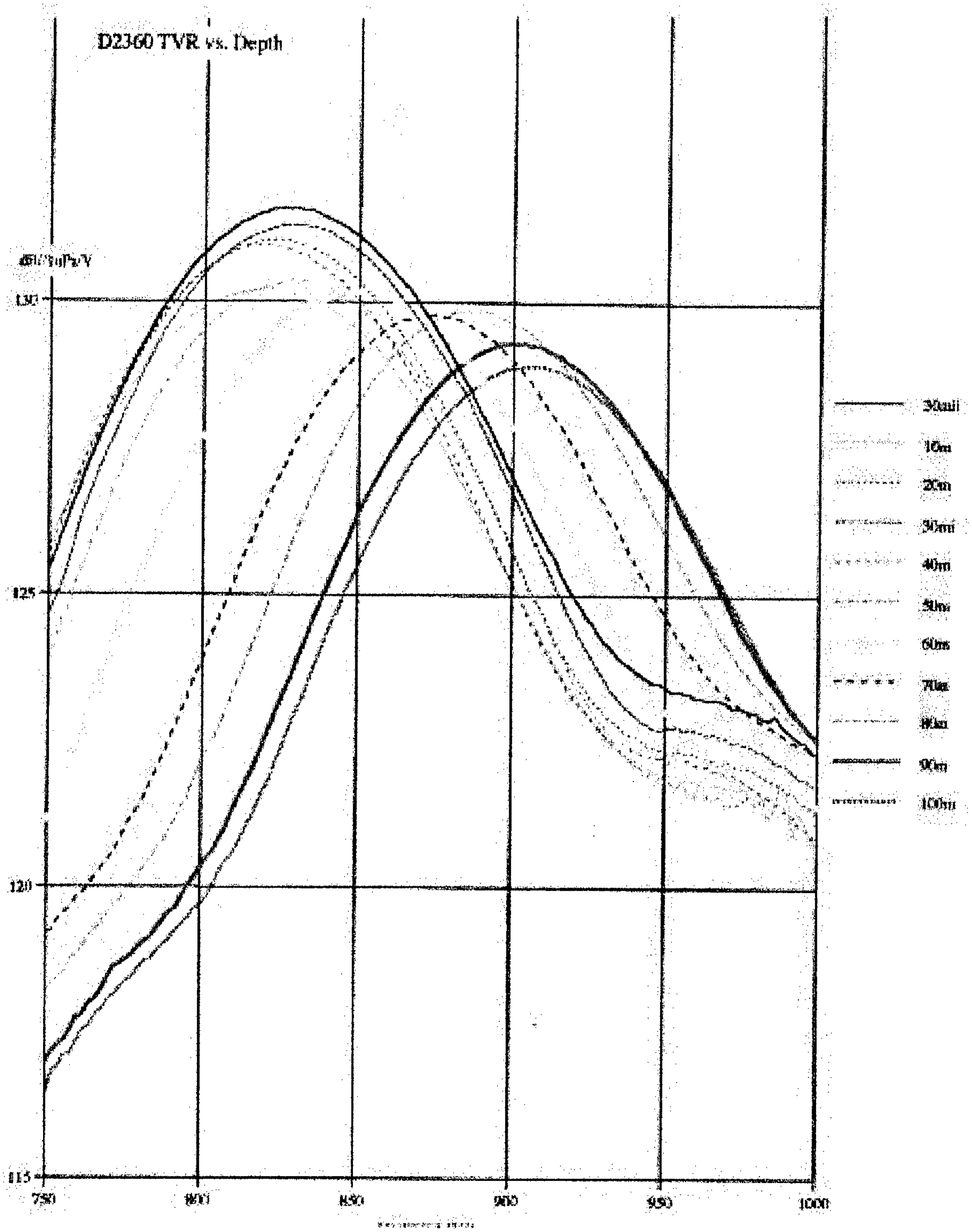

Fig. 5. Measured TVR characteristics of transducer D2360 vs. depth.

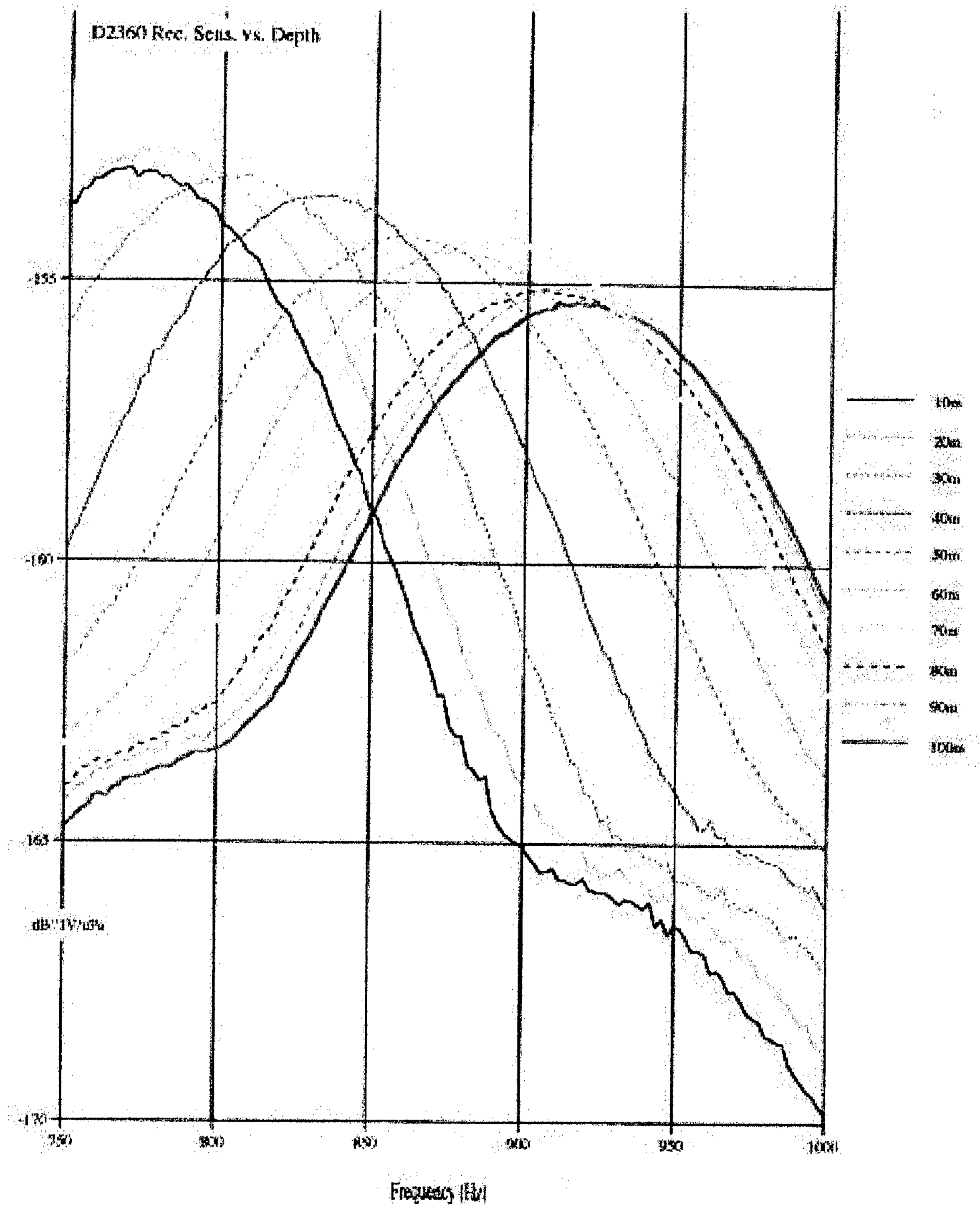

Fig. 6. Measured FFVS characteristics of transducer D2360 vs. depth.

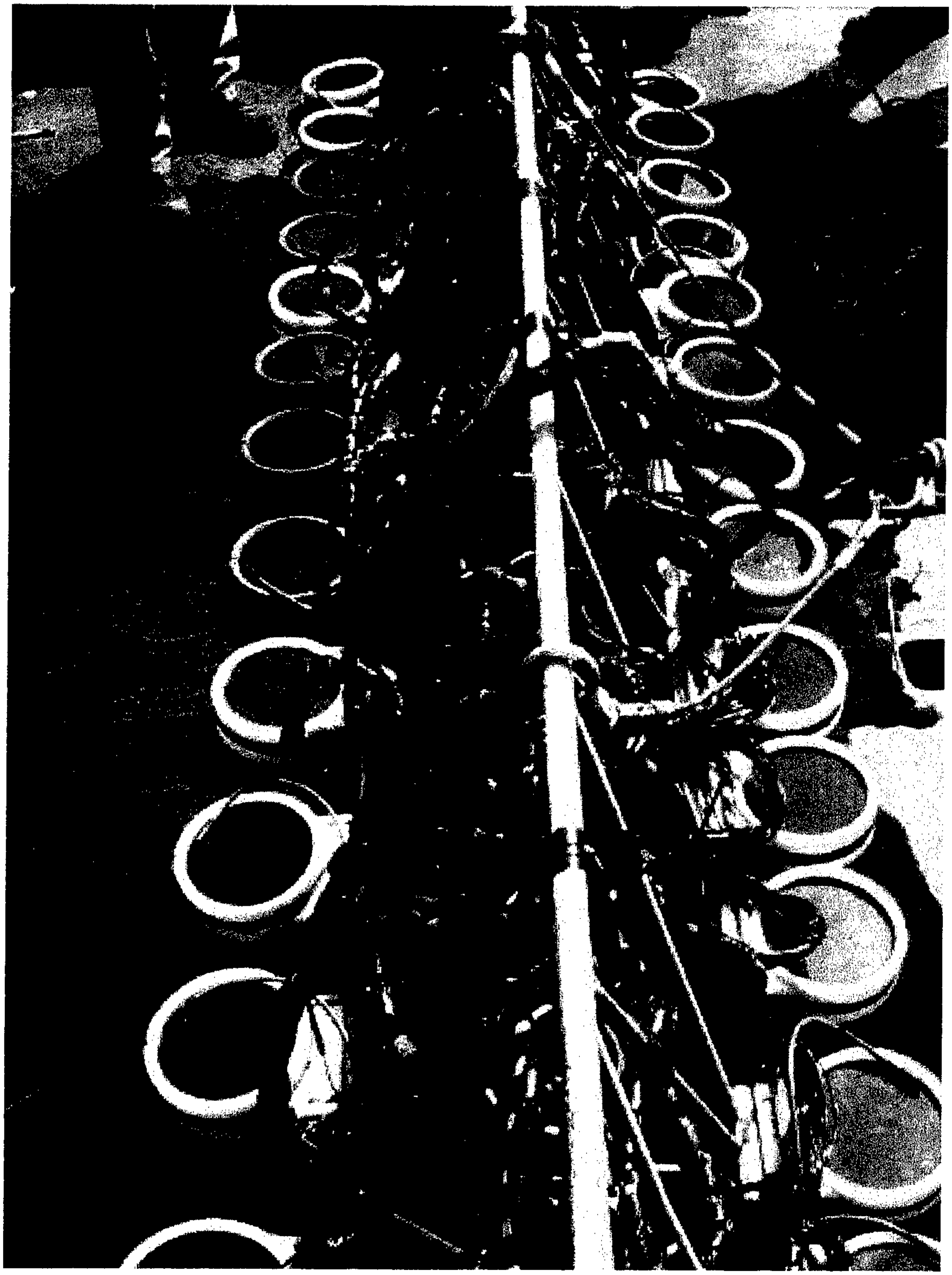

Fig. 7. Mid-frequency transducers configured for in-situ testing early in FAF-03.

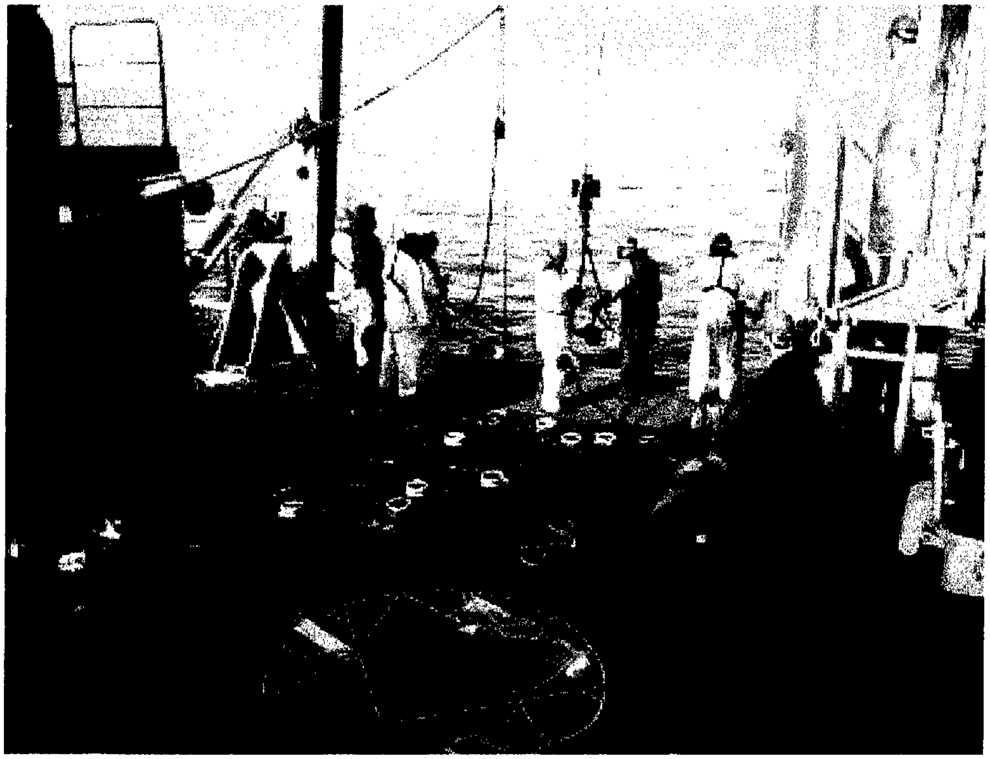

Fig. 8. Mid-frequency transducers on the back deck of the R/V Alliance during FAF-03 in preparation for deployment as a 78 m aperture vertical source-receive array.

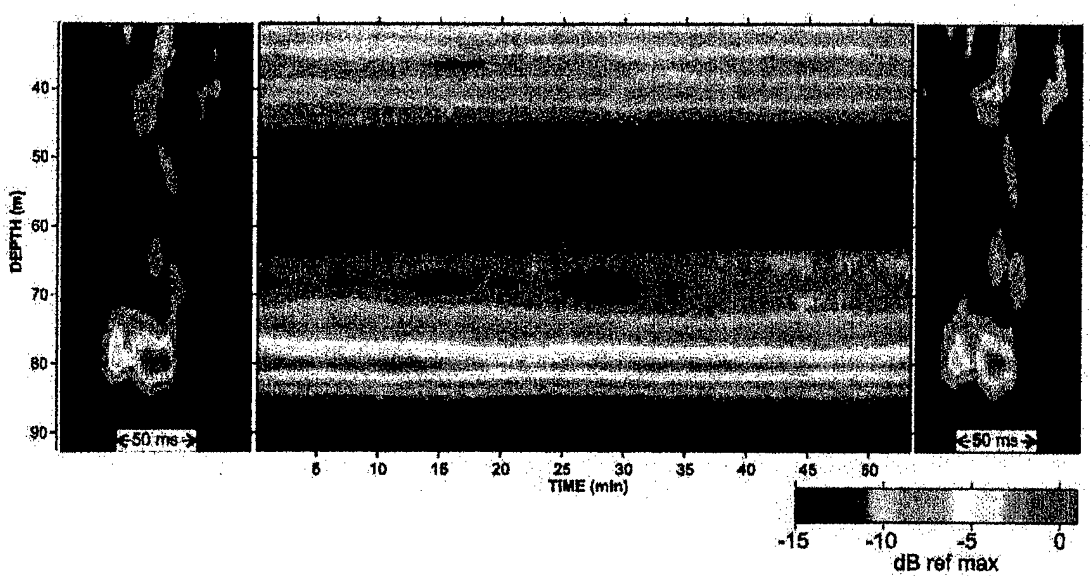

Fig. 9. Time reversal focusing during FAF-03 at 850 Hz over a 10 km range for a period of 55 min.

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